California Air Resources Board

Greenhouse Gas Quantification Methodology for the Department of Forestry & Fire Protection Forest Health Program

Greenhouse Gas Reduction Fund Fiscal Year 2016-17

May 5, 2017

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Section A. Introduction

The goal of California Climate Investments is to reduce greenhouse gas (GHG) emissions and further the purposes of the Global Warming Solutions Act of 2006, known as Assembly Bill (AB) 32. The California Air Resources Board (CARB) is responsible for providing the quantification methodology to estimate the net GHG benefit and other benefits from projects receiving monies from the Greenhouse Gas Reduction Fund (GGRF). CARB develops these methodologies based on the project types eligible for funding by each administering agency as reflected in the program Expenditure Records available at: https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/expenditurerecords.htm. CARB staff periodically review each quantification methodology to evaluate its effectiveness and update methodologies to make them more robust, user-friendly, and appropriate to the projects being quantified.

For the CAL FIRE Forest Health Program, CARB staff developed this quantification methodology and Forest Health GHG Calculator Tool to provide methods for estimating net GHG benefits of each proposed project (Section B), provide instructions for documenting and supporting the estimate (Section C), and outline the process for tracking and reporting GHG and other benefits once a project is funded (Section D).

This methodology uses calculations to estimate the net GHG benefit of forest health activities including reforestation, forest pest management, fuels reduction, forest conservation, and biomass utilization. Calculations account for on-site forest carbon stocks, carbon stored in wood products, the displacement of fossil fuels that results from biomass energy generation, and GHG emissions associated with the implementation of forest health projects. Projects will report the total project GHG benefit estimated using this methodology as well as the total project GHG benefit per dollar of GGRF funds requested.

Forest Health Activity Types

CAL FIRE developed five activity types that meet the objectives of the Forest Health Program and for which there are methods to quantify a net GHG benefit. Each project requesting GGRF funding must include at least one of the following project components for FY 2016-17:

- Reforestation;
- Pest Management;
- Fuels Reduction;
- Forest Conservation; and
- Biomass Utilization.

Section B of this quantification methodology details the methods to use based on the project component(s) proposed.

Methodology Development

CARB and CAL FIRE developed this quantification methodology consistent with the guiding implementation principles of California Climate Investments, including ensuring transparency and accountability.[i] CARB and CAL FIRE developed this quantification methodology through a public process to be used to estimate the outcomes of proposed projects, inform project selection, and track results of funded projects. The implementing principles ensure that the methodology would:

- Apply at the project-level;
- Provide uniform methods to be applied statewide, and be accessible by all applicants;
- Use existing and proven tools and methods;
- Use project-level data, where available and appropriate; and
- Result in GHG emissions-reduction estimates that are conservative and supported by empirical literature.

CARB assessed peer-reviewed literature and tools and consulted with experts, as needed, to determine methods appropriate for the forest health activity types. CARB also consulted with CAL FIRE to determine project-level inputs available. The methods were developed to provide estimates that are as accurate as possible with data readily available at the project level. CARB released a draft FY 2016-17 quantification methodology for public comment in February 2017.

Tools

This quantification methodology and the Forest Health Program GHG Calculator Tool rely on project-specific outputs from the following tools:

The U.S. Forest Service (USFS) Carbon On Line Estimator (COLE) Version 3.0 provides carbon stock estimates based on forest location and characteristics. COLE data are based on USDA Forest Service Forest Inventory & Analysis and Resource Planning Assessment data, enhanced by other ecological data. COLE can be used by applicants to estimate carbon stocks for reforestation, pest management, and forest conservation activities within a forest health project. The tool is used statewide, publicly available, subject to regular updates to incorporate new information, is free of charge, and available to anyone with internet access. The tool can be accessed at: http://www.ncasi2.org/GCOLE3/gcole.shtml.

Tree growth and yield models simulate a range of silvicultural treatments and provide carbon stock estimates based on individual tree and stand data. This quantification methodology provides guidance for using the USFS Forest Vegetation Simulator (FVS) but applicants may choose to use alternative models including: Forest and Stand Evaluation Environment (FORSEE), California Conifer Timber Output Simulator (CACTOS), Stand Projection System (SPS), or Forest Projection System (FPS). Growth and yield models can be used by applicants to estimate carbon stocks for reforestation, pest management, fuels reduction and forest conservation activities within a forest health project. FVS is used statewide, publicly available, subject to regular updates to incorporate new information, is free of charge, and available to anyone with internet access. The tool can be accessed at: http://www.fs.fed.us/fmsc/fvs/.

Forest fire models simulate fire behavior and effects including impacts on carbon stocks. This quantification methodology provides guidance for using two USFS tools, the Fire and Fuels Extension of FVS (FFE-FVS) and FlamMap but applicants may choose to use alternative models including Consume and First Order Fire Effects Model (FOFEM). Forest fire models can be used by applicants to estimate reduced loss in carbon stocks from wildfire for fuels reduction activities within a forest health project. FFE-FVS and FlamMap are used statewide, publicly available, subject to regular updates to incorporate new information, free of charge, and available to anyone with internet access. The tools can be accessed at: http://www.fs.fed.us/fmsc/fvs/ and https://www.firelab.org/project/flammap.

Applicants will choose from the appropriate tools listed for each activity in Table 2 and do not need to use the same tools for all activities that comprise the project.

Applicants must use this quantification methodology, in conjunction with the accompanying Forest Health GHG Calculator Tool, to estimate the net GHG benefit of the proposed project. The Forest Health GHG Calculator Tool can be downloaded from: www.arb.ca.gov/cci-quantification

Major Updates

CARB updated this quantification methodology from the previous version.[ii] The major changes include:

- Required use of this standardized quantification methodology;
- Addition of a GHG quantification method for landscape level projects that may involve multiple activities that improve forest health and resiliency;
- Changes in the length of time over which GHG benefits are calculated;
- Inclusion of additional tools for carbon stock accounting;
- Modified guidance on which carbon pools to include in the accounting boundary;
- Addition of an emission reduction factor for electricity generation via gasification;
- Inclusion of method to estimate emissions from project implementation;
- Development of an accompanying Forest Health GHG Calculator Tool to assist with quantification; and
- Addition of information from the approved CARB *Funding Guidelines for Agencies Administering California Climate Investments* (Funding Guidelines)[iii] on reporting after a project is selected for funding (see Section D of this document for details).

Program Assistance

CARB and CAL FIRE staff will review the quantification portions of the Forest Health Program project applications to ensure that the methods described in this document were properly applied to estimate the net GHG benefit for the proposed project. Applicants should use the following resources for additional questions and comments:

- Questions on this document should be sent to GGRFProgram@arb.ca.gov.
- For more information on CARB's efforts to support implementation of GGRF investments, see: www.arb.ca.gov/caclimateinvestments.
- Questions pertaining to the Forest Health Program should be sent to calfire.grants@fire.ca.gov.

Section B. GHG Quantification Methodology

Overview

This quantification methodology accounts for on-site forest carbon stocks, carbon stored in wood products, the displacement of fossil fuels that results from biomass energy generation, and GHG emissions associated with the implementation of forest health projects. In general, the net GHG benefit is calculated using the following approaches:

Table 1. General Approach to GHG Quantification by Project Activity

Reforestation
Net GHG Benefit = Δ in standing live and dead tree carbon stocks in the treatment boundary – carbon in shrubs and herbaceous understory removed from treatment boundary – emissions from site preparation and herbicide treatments
Pest Management
Net GHG Benefit = Δ in standing live tree carbon stocks in the treatment and impact boundaries as a result of reduced mortality from pests and disease – carbon in biomass removed from treatment boundary – mobile combustion emissions from mechanical treatments
Fuels Reduction
Net GHG Benefit = Δ in standing live tree carbon stocks in the treatment boundary and impact boundary (optional) as a result of reduced mortality from wildfire – carbon in biomass removed from treatment boundary – mobile combustion emissions from mechanical treatments
Forest Conservation
Net GHG Benefit = Δ in standing live and dead tree carbon stocks in the treatment boundary as a result of avoided conversion and ongoing forest management[1]
Biomass Utilization
Net GHG Benefit = Carbon stored long-term in wood products + avoided emissions from fossil fuel-based energy displaced by biomass energy – stationary combustion emissions from biomass energy production + avoided emissions from alternative form of biomass disposal[2]

[1] Forest conservation activities are expected to impact long-term biomass removal and utilization and therefore biomass that would be removed and utilized in the conservation baseline and project scenarios are calculated as part of the biomass utilization activity.
[2] Avoided biomass disposal emissions are only included for projects that involve the utilization of biomass that would otherwise be removed (i.e., biomass removal is not funded by GGRF) and landfilling, open pile burning or on-site decay is expected in the baseline scenario (i.e., in the absence of the project). Avoided disposal emissions of material that would only require disposal as a result of the project is not accounted for.

Applicants will follow the steps outlined in Figure 1 to estimate the net GHG benefit from the proposed project. Detailed instructions for each step are provided on subsequent pages.

Figure 1. Steps to Estimating Net GHG Benefits

Step 1. Identify Project Activities and Appropriate Quantification Methods for the Proposed Project

Step 2. Determine the Forest Health GHG Calculator Tool Inputs Appropriate to the Project Activities

Step 3. Use On-Site Carbon Stock Accounting Tools to Determine Inputs for the Forest Health GHG Calculator Tool

Step 4. Determine Look-Up Values for the Forest Health GHG Calculator Tool

Step 5. Estimate the Net GHG Benefit Using the Forest Health GHG Calculator Tool

Step 1: Identify the Appropriate Quantification Methods for the Proposed Project Activities

For GHG quantification purposes, eligible forest health projects may include one or more of five eligible on-the-ground activity types. Applicants may incorporate more than one activity and can use multiple methods identified in this quantification methodology, as appropriate, to quantify the net GHG benefit. Applicants must identify the project activities from Table 2 that apply to the project. The project activities identified will determine which 1) subsections of this quantification methodology to be used in order to estimate the net GHG benefit, 2) which on-site carbon stock accounting tools may be used, and 3) which on-site carbon pools are included when estimating the GHG benefit for each eligible activity.

Table 2. Project Activities and Appropriate Quantification Methods

Project Activity	Method Subsection Reference	On-Site Carbon Stock Accounting Tools	Included On-Site Carbon Pools
Reforestation	Step 2 Step 3.A or 3.B Step 4.A Step 5	• COLE; or • Growth and Yield Model	• Standing Live Trees • Standing Dead Trees • Shrubs and Herbaceous Understory
Pest Management	Step 2 Step 3.A or 3.B Step 4.B Step 5	• COLE; or • Growth and Yield Model	• Standing Live Trees[3]
Fuels Reduction	Step 2 Step 3.B Step 3.C Step 4.C Step 5	• Growth and Yield Model and • Forest Fire Model	• Standing Live Trees[3]
Forest Conservation	Step 2 Step 3.A or 3.B Step 5	• COLE; or • Growth and Yield Model	• Standing Live Trees • Standing Dead Trees
Biomass Utilization	Step 2 Step 5	Not Applicable[4]	Not Applicable[5]

[3] Pest management and fuels reduction activities may involve the removal of standing dead trees and shrubs and herbaceous understory for the purpose of minimizing potential mortality of surrounding live trees (a shift from the standing live to the standing dead carbon pools). These pools are excluded for the purpose of this quantification methodology because, if included, the carbon stock change approach to accounting would not distinguish the significant difference in the value between carbon stored the live and dead pools.

[4] On-site carbon stocks are not calculated for biomass utilization activities. Applicants must estimate the quantity of biomass to be utilized by analyzing the amount of biomass to be removed, based on current stand conditions and proposed treatments to be implemented, and percentage of removed biomass expected to be utilized.

[5] On-site carbon pools are not included in accounting for biomass utilization activities. The net GHG benefit is quantified by assessing carbon stored long-term in wood products, fossil fuel displacement from biomass electricity generation, and avoided landfill, open pile burn and on-site decay emissions.

Step 2: Determine the Forest Health GHG Calculator Tool Inputs Needed

This section describes the data inputs needed to estimate the net GHG benefit of each forest health activity using the accompanying Forest Health GHG Calculator Tool. For the purposes of quantification, the end of the project is defined as 50 to 80 years after project start, depending on the site class category of the project lands.[6] Projects must determine the inputs needed for each activity included in the project.

All activities except biomass utilization require estimates of on-site carbon stocks within a "treatment boundary." Pest management and fuels reduction activities can impact the carbon stocks beyond their treatment boundaries; therefore this methodology also accounts for estimates of on-site carbon stocks within an "impact boundary" for those activities.[7]

Project Boundary Definitions:
The treatment boundary is defined as the geographic area in which forest treatments will occur. The treatment boundary applies to all activity types.

The impact boundary is defined as the geographic area beyond a pest management or fuels reduction treatment boundary where the treatments reduce the risk of future carbon stock loss. Treatment boundaries are not included in impact boundaries.

- The impact boundary of a pest management activity is the overall project site (i.e., the external boundary that encompasses all project treatments).
- The impact boundary of a fuels reduction activity, sometimes referred to as the shadow effect, is the area in which fuel reduction activities are intended to protect by modifying fire behavior. Applicants can determine the impact boundary based on modeled or observed fire behavior.

Landscape level projects that involve multiple activities may involve instances where various treatment and/or impact boundaries overlap within the overall project area. To avoid double counting carbon stocks on the landscape, applicants with projects that contain overlapping boundaries must follow the approach of apportioning the acreage within the overlapping boundaries detailed in Table 3. Generally, treatment boundaries take precedence over impact boundaries, treatment boundaries for activities that involve active management (pest management and fuels reduction) take precedence over forest conservation treatment boundaries, and treatment boundaries activities that establish future stands (reforestation) take precedence over activities that serve to protect future stands (forest conservation, pest management, and fuels reduction).

[6] 50 years for site class I, 60 years for site classes II and III, and 80 years for site classes IV and higher. If a project includes forestlands of different site classes with different corresponding project end dates, the shortest length of time will be used for the entire project.
[7] Including GHG benefits from the impact boundary is optional for fuels reduction activities.

Table 3. Approach for Apportioning Acreage Within Overlapping Boundaries

Boundary 1	Boundary 2	Apportioning Approach
Forest conservation treatment boundary	Fuels reduction impact boundary	Include acreage within overlapping area when quantifying forest conservation activity.
		Exclude acreage within overlapping area when quantifying fuels reduction activity.
Forest conservation treatment boundary	Pest management impact boundary	Include acreage within overlapping area when quantifying forest conservation activity.
		Exclude acreage within overlapping area when quantifying pest management activity.
Reforestation treatment boundary	Fuels reduction impact boundary	Include acreage within overlapping area when quantifying reforestation activity.
		Exclude acreage within overlapping area when quantifying fuels reduction activity.
Reforestation treatment boundary	Pest management impact boundary	Include acreage within overlapping area when quantifying reforestation activity.
		Exclude acreage within overlapping area when quantifying pest management activity.
Pest management treatment boundary	Fuels reduction impact boundary	Include acreage within overlapping area when quantifying pest management activity.
		Exclude acreage within overlapping area when quantifying fuels reduction activity.
Fuels reduction treatment boundary	Pest management impact boundary	Include acreage within overlapping area when quantifying fuels reduction activity.
		Exclude acreage within overlapping area when quantifying pest management activity.
Forest conservation treatment boundary	Fuels reduction treatment boundary	Include acreage within overlapping area when quantifying fuels reduction activity.
		Exclude acreage within overlapping area when quantifying forest conservation activity.
Forest conservation treatment boundary	Pest management treatment boundary	Include acreage within overlapping area when quantifying pest management activity.
		Exclude acreage within overlapping area when quantifying forest conservation activity.
Forest conservation treatment boundary	Reforestation treatment boundary	Include acreage within overlapping area when quantifying reforestation activity.
		Exclude acreage within overlapping area when quantifying forest conservation activity.
Reforestation treatment boundary	Pest management treatment boundary	Include acreage within overlapping area when quantifying reforestation activity.
		Exclude acreage within overlapping area when quantifying pest management activity.
Pest management treatment boundary	Fuels reduction treatment boundary	Applicants will choose to include acreage within the overlapping area in only one of the boundaries.
Pest management impact boundary	Fuels reduction impact boundary	Applicants will choose to include acreage within the overlapping area in only one of the boundaries.
Reforestation treatment boundary	Fuels reduction treatment boundary	Not applicable; it is not expected that these two activities will have overlapping treatment boundaries.

Table 4 identifies the required data inputs needed to estimate the net GHG benefit for proposed projects with the Forest Health GHG Calculator Tool.

Table 4. Required Forest Health GHG Calculator Tool Inputs for Eligible Project Activities

<table>
<tr><th colspan="2">ALL PROJECTS</th></tr>
<tr><td colspan="2">General Information (Read Me worksheet)
• Project Name;
• Grant ID, if applicable;
• Contact Name;
• Contact Phone Number;
• Contact Email; and
• Date Completed.

Total Project GHG Benefit/GGRF $ Requested (GHG Summary worksheet)
• Total amount of Forest Health Program GGRF funds requested to implement the project; and
• Total amount of GGRF funds requested to implement the project.</td></tr>
<tr><th colspan="2">REFORESTATION</th></tr>
<tr><td colspan="2">Greenhouse Gas Quantification Inputs (Reforestation worksheet)</td></tr>
<tr><td>Carbon within the treatment boundary at the end of the project with reforestation (MT C)</td><td>Carbon stored in existing and planted standing live and dead trees within the treatment boundary at the end of the project in reforestation project scenario.</td></tr>
<tr><td>Carbon within the treatment boundary at the end of the project without reforestation (MT C)</td><td>Carbon stored in existing standing live and dead trees within the treatment boundary at the end of the project in reforestation baseline scenario.</td></tr>
<tr><td>Area subject to site preparation (acres)</td><td>Acres within the treatment boundary subject to site preparation.</td></tr>
<tr><td>Area subject to herbicide treatment (acres)</td><td>Acres within the treatment boundary subject to herbicide treatment.</td></tr>
<tr><td>Level of brush cover</td><td>If site preparation is planned, choose level of brush cover (light: 0-25% brush cover, medium: >25%-50% dense brush cover, or heavy: >50% brush cover and/or stump removal) that best describes land cover of area subject to site preparation prior to project implementation (used to account for mobile source combustion emissions).</td></tr>
<tr><td>Land cover type</td><td>If site preparation is planned, choose land cover type (grass, light to medium shrubs, or heavy shrubs) that best describes land cover prior to project implementation.</td></tr>
</table>

PEST MANAGEMENT	
Greenhouse Gas Quantification Inputs (Pest Management worksheet)	
Carbon within the treatment boundary at the end of the project *without disturbance or pest management treatment* (MT C)	Carbon stored in standing live trees within the treatment boundary at the end of the project assuming no pest management treatment and no threat from pests or disease.
Carbon within the impact boundary at the end of the project *without disturbance or pest management treatment* (MT C)	Carbon stored in standing live trees within the impact boundary at the end of the project assuming no pest management treatment and no threat from pests or disease.
Percentage of treatment and impact boundaries at risk *with pest management treatment* (%)	Percentage of treed area within the treatment and impact boundaries that remains at risk from pests and disease within a 10-year time frame with pest management treatment. Applicants may provide site- and treatment-specific estimates sourced from published, peer-reviewed literature directly applicable to the project site or from a Registered Professional Forester or Certified Silviculturist familiar with the threat facing the project site and proposed treatments.[8]
Percentage of treatment and impact boundaries at risk *without pest management treatment* (%)	Percentage of treed area within the treatment and impact boundaries at risk from pests and disease within a 10-year time frame without pest management treatment. Applicants may provide 1) site-specific estimates sourced from the USFS National Insect and Disease Risk Map (NIDRM), 2) site-specific estimates sourced from published, peer-reviewed literature directly applicable to the project site, or 3) site-specific estimates from a Registered Professional Forester or Certified Silviculturist familiar with the threat facing the project site.[8]
Carbon removed as part of pest management treatment (MT C)	Amount of standing live tree carbon to be removed from within the treatment boundary as part of pest management treatment.[9]
Biomass removed via mechanical treatments (BDT[10])	Amount of biomass[11] to be removed from within the treatment boundary via mechanical treatments (used to account for mobile source combustion emissions).

[8] At a minimum, projects must consider the following when determining the baseline and project mortality rates within the project site: the local extent and scale of the epidemic, the type of treatment to be implemented, the species threatened by the pest or disease, the species composition and density within the project site, whether the pest is native or exotic, and the climate of the project site.
[9] Applicants must estimate the quantity of standing live tree carbon to be removed by analyzing current stand conditions and proposed treatments to be implemented.
[10] The Forest Health GHG Calculator Tool can be used to convert cubic feet (ft^3) to bone dry tons (BDT) for various forest types.
[11] For the purposes of this quantification methodology, “biomass” refers to both merchantable timber and woody waste material.

FUELS REDUCTION	
Greenhouse Gas Quantification Inputs (Fuels Reductions worksheet)	
Annual probability of fire occurrence (%)	Annual probability that area within the treatment and impact boundaries will be subject to wildfire disturbance.
Effective period for fuels reduction treatment (Years)	Length of time fuels reduction treatment is expected to be effective at modifying fire behavior (maximum of 25 years). Applicants can determine the effective period based on modeled or observed change in fire behavior as a result of the treatment and/or the professional judgement of the Registered Professional Forester or Certified Silviculturist designing the treatment.
Carbon within the treatment boundary at the end of the project *with fuels reduction treatment but without fire disturbance* (MT C)	Carbon stored in standing live trees within the treatment boundary at the end of the project assuming no disturbance from wildfire and fuels reduction treatment was implemented.
Carbon within the impact boundary at the end of the project *without fire disturbance*[12,13] (optional[14]) (MT C)	Carbon stored in standing live trees within the impact boundary at the end of the project assuming no disturbance from wildfire.
Carbon within the treatment boundary at the end of the project *with fuels reduction treatment and with fire disturbance* (MT C)	Carbon stored in standing live trees within the treatment boundary at the end of the project assuming a disturbance from wildfire and fuels reduction treatment was implemented.
Carbon within the impact boundary at the end of the project *without fuels reduction treatment but with fire disturbance* (optional[14]) (MT C)	Carbon stored in standing live trees within the impact boundary at the end of the project assuming a disturbance from wildfire and no fuels reduction treatment.
Carbon within the treatment boundary at the end of the project *without fuels reduction treatment and without fire disturbance* (MT C)	Carbon stored in standing live trees within the treatment boundary at the end of the project assuming no disturbance from wildfire and no fuels reduction treatment.
Carbon within the treatment boundary at the end of the project *without fuels reduction treatment but with fire disturbance* (MT C)	Carbon stored in standing live trees within the treatment boundary at the end of the project assuming a disturbance from wildfire and no fuels reduction treatment.
Proportion of impact boundary likely to burn at high severity *without fuels reduction treatment*[13] (optional[14]) (%)	Proportion of area within the impact boundary (%) with >50% probability of experiencing high flame lengths (>8 ft), based on Monte Carlo simulations[15] of wildfire across the landscape without fuels reduction treatment
Proportion of impact boundary likely to burn at high severity *with fuels reduction treatment*[13] (optional[14]) (%)	Proportion of area within the impact boundary (%) with >50% probability of experiencing high flame lengths (>8 ft), based on Monte Carlo simulations[15] of wildfire across the landscape with fuels reduction treatment
Biomass removed via mechanical treatments (BDT[10])	Amount of biomass[11] removed from within the treatment boundary via mechanical treatment (used to account for mobile source combustion emissions).

[12] This impact boundary without fire carbon value will be the same in the baseline and project scenarios.
[13] These values are also used to calculate the impact boundary with treatment and fire carbon value.
[14] Including GHG benefits from the impact boundary is optional for fuels reduction activities.
[15] Using Minimum Travel Time model in the FlamMap fire behavior software package.

FOREST CONSERVATION	
Greenhouse Gas Quantification Inputs (Conservation worksheet)	
Carbon within the treatment boundary at the end of the project *with the conservation easement* (MT C)	Carbon stored in standing live and dead trees within the treatment boundary at the end of the project with the conservation easement.
Type of conversion threat	Choose the type of conversion threat facing the land.
If conversion threat is residential, number of parcels (parcels)	If conversion threat is residential, number of unique parcels that would be formed in the treatment boundary (used to calculate conversion impact).
If conversion threat type is residential, area of treatment boundary (acres)	If conversion threat is residential, size of forested area to be placed under conservation easement
Biomass that would be removed from within the treatment boundary and utilized *without the conservation easement* (BDT)[10]	Amount of biomass[11] that would be removed from within the treatment boundary and utilized for wood products, electricity generation via combustion, and electricity generation via gasification. Estimate biomass that would be utilized if land were converted without the conservation easement. Provide separate estimates for each method of utilization.[16]
Biomass that is expected to be removed from treatment boundary and utilized *with the conservation easement* (BDT)[10]	Amount of biomass[11] that is expected to be removed from within the treatment boundary and utilized for wood products, electricity generation via combustion, and electricity generation via gasification. Estimate biomass to be utilized with the conservation easement during the 50-80 year project but after project closeout (i.e., biomass removal not funded with GGRF but as a result of the area continuing to operate as a working forest). Provide separate estimates for each method of utilization.[17]

[16] Applicants must estimate the quantity of biomass to be utilized if the area were to be converted by analyzing the amount of biomass to be removed, based on current stand conditions, and percentage of removed biomass expected to be utilized.

[17] Applicants must estimate the quantity of biomass to be utilized in the 50 to 80 years after project start by analyzing recent harvesting trends on the land and taking into account any new practices being introduced by the terms of the easement.

BIOMASS UTILIZATION	
Greenhouse Gas Quantification Inputs (Biomass Utilization worksheet)	
For biomass utilization activities that send biomass to a mill	
Biomass to be removed (with and without GGRF funding) and delivered to a mill as part of the project (BDT[10])	Total amount of biomass[11] to be removed from the project area (removed with and without GGRF funding) and delivered to a mill during project implementation.
Mill efficiency (%)	Efficiency of the mill where merchantable biomass is delivered (if not available from mill, default mill efficiencies are provided).
Wood product classes (%)	Percentage of merchantable biomass that will go into each wood product class category (if not available from mill, default wood product class is provided).
For biomass utilization activities that send biomass to a biomass energy facility	
Biomass to be removed (with and without GGRF funding) and delivered to a biomass facility generating electricity via combustion as part of the project (BDT[10])	Total amount of biomass[11] that is expected to be removed from the project area (removed with and without GGRF funding) and delivered to a biomass facility generating electricity via combustion during project implementation.
Biomass to be removed (with and without GGRF funding) and delivered to a biomass facility generating electricity via gasification as part of the project (BDT[10])	Total amount of biomass[11] that is expected to be removed from the project area (removed with and without GGRF funding) and delivered to a biomass facility generating electricity via gasification during project implementation.
For biomass utilization activities that utilize biomass that is removed by actions not funded by GGRF (i.e., removal would occur without GGRF funding)	
Biomass that would be removed and open pile burned without project(BDT[10])	Amount of biomass[11] that would be removed and open pile burned in baseline scenario (do not include biomass that is removed as part of the project; in the absence of the project, this material would not be open pile burned).
Biomass that would be removed and landfilled without project (BDT[10])	Amount of biomass[11] that would be removed and landfilled in baseline scenario (do not include biomass that is removed as part of the project; in the absence of the project, this material would not be landfilled).
Biomass that would be removed and left to decay on-site without project (BDT[10])	Amount of biomass[11] that would be removed and left to decay on-site in baseline scenario (do not include biomass that is removed as part of the project; in the absence of the project, this material would not be left to decay on-site).

Step 3: Use the On-Site Carbon Stock Accounting Tools to Determine Inputs for the Forest Health GHG Calculator Tool

This section provides instructions for estimating on-site carbon stocks. Applicants must follow the instructions for the tools identified for use Table 2 based on activity type.

A. Carbon On Line Estimator

Reforestation, pest management, and forest conservation activities may use COLE or the alternative carbon stock accounting tools identified for those activities in Table 2. For reforestation activities, COLE can only be used to estimate on-site carbon stocks in the project scenario. If using COLE to estimate on-site carbon stocks for a reforestation activity; the baseline scenario must be estimated using the reforestation baseline look up table found in Step 4.A.

Table 5 describes the data inputs needed if the applicant is using COLE to estimate on-site carbon stocks.

Table 5. Required Inputs for Estimating On-Site Carbon Stocks Using COLE

COLE
• Location of project • Forest type or forest type group • Owner group • Site productivity class (ft^3/acre/year)

After collecting the necessary data, applicants will follow the guidance below to estimate the on-site carbon stocks at the end of the project. For pest management and forest conservation activities, applicants will input carbon stock values from COLE that represent no threat of conversion or disturbance from pests and disease into the Forest Health GHG Calculator Tool.

i. In the Select Data tab, select “plots within the radius (km),” double click the project area on the map (zoom into the map as needed), and click “get data” and wait until the request is processed;
ii. For reforestation projects, in the Filters tab, scroll down to the “All Live Stocking Code” window and select “fully stocked” and “medium stocked”;
iii. In the Filters tab, scroll down to the “Forest Type” window and select the forest type or forest type group of the project area;
iv. In the Filters tab, scroll down to the “Owner Group” window and select the forest type(s) or owner group type(s) of the project area;
v. In the Filters tab, scroll down to the “Site Productivity Class” window and select the appropriate site productivity class for the project area (see table below) as well as the next lowest and highest productivity classes, if available;

Table 6. Crosswalk for Site Productivity Class

FIA Class	Site Productivity Class in COLE (ft^3/acre/year)	Forest Practice Site Class by Species		
		Mixed Conifer	Douglas-Fir	Redwood
1	225+	I	I	I
2	165-224	II	I, II	II
3	120-164	III	III	III
4	85-119	IV	IV	IV, V
5	50-84	V	V	V
6, 7	0-49	V	V	V

vi. For reforestation activities, in the Filters tab, scroll down to the “Stand Origin” window and select “Planted” and “Natural”;

vii. In the Filters tab, click the green “Filter Map” button and wait until the request is processed;

viii. In the Report tab, click the green submit button and wait for the pop-up window to appear; in the pop-up window, click “Click here for your carbon report”;

ix. Scroll down to Table 1 within the report and find the carbon estimates under the “Live tree” column and, if being used to for a reforestation or forest conservation activity, the “Dead tree” column at the average age of the stand at the end of the project (MT C/ha);

x. If more than one carbon pool is included in accounting, add the carbon estimates for each pool from Step ix together; and

xi. Divide the total carbon estimate from Step x (MT C/ha) by 2.47 to calculate the metric carbon per acre (MT C/acre); and[18]

xii. Multiply the estimate from Step xi (MT C/acre) by the acres within the treatment boundary to convert to metric tons (MT C).[18] If a pest management activity, repeat using the acres within the impact boundary to determine the MT C in the impact boundary.

[18] These calculations can also be done within the conversions tab of the Forest Health GHG Calculator Tool.

B. Growth and Yield Models

This section provides guidance on using a growth and yield model to estimate on-site carbon stocks. In addition to general instructions, this quantification methodology provides guidance specific to modeling the baseline and project scenarios using FVS but applicants may undertake a similar process using one of the alternative growth and yield models identified in Step 1. If choosing to use one of the alternative models (FORSEE, CACTOS, SPS or FPS), applicants must still follow the methods presented below (e.g., how to source tree data, what must be captured in the baseline and project scenarios, and which carbon pools need to be estimated based on activity type) but the step-by-step instructions for using FVS may not apply. In addition to the guidance provided in this quantification methodology, additional resources including FVS user guides and training materials are available at http://www.fs.fed.us/fmsc/fvs/index.shtml. Table 7 describes the necessary tree[19] and stand data inputs required to estimate on-site carbon stocks using FVS.

Table 7. Required Data for Estimating On-Site Carbon Stocks Using FVS

Minimum Tree Data
Input files must include the following data for standing live trees ≥5 inches in diameter at breast height[20] (DBH) and, if an included carbon pool per Table 2, standing dead trees ≥5 inches in DBH: • Tree species (FVS 2-letter code or Forest Inventory Analysis (FIA) species code) • DBH (inches) • Tree history code (i.e., 0-5 for standing live or 6-9 for standing dead[21])
Minimum Stand Level Parameters
FVS inputs will include the details of proposed treatments as well as stand characteristics including: • Stand ID • Inventory year • Large tree plot size • Small tree plot size • Number of plots • Breakpoint DBH (i.e., 5 inches) • Group name (used to differentiate between treatment and impact boundary stands) • Forest type • Forest Service region (i.e., Pacific Southwest) • Forest Service forest (i.e., nearest national forest) • FVS variant (i.e. Western Sierra Nevada, Klamath Mountains, Inland California and Southern Cascades) • Maximum stand density index • Site index and site index species

[19] Tree data is not required for reforestation activities where planting is taking place on bare ground.
[20] Diameter outside bark, measured at breast height 4.5 feet (1.37m) above the ground or at root collar.
[21] For the purposes of this quantification methodology, applicants need not distinguish between the various codes within the live and dead tree categories but must use the codes to designate sampled trees as either alive or dead.

In addition to the parameters above, the following stand characteristics must also be input for stands involving fuels reduction activities:

- Aspect
- Slope
- Location
- Elevation
- Surface fuels information

Individual Tree Data

Individual tree data serve as the basis for modeling and estimating carbon stocks over time. Data may be obtained from one of the following sources:

1. Forest Stand Inventory: An inventory of trees within the treatment and/or impact boundaries or of nearby lands with sufficiently similar site characteristics (i.e., species composition, age class distribution, stocking levels, etc.) and management practices. Applicants may only use inventory data recorded within the last twelve years. A sufficient number of plots must be measured to provide a statistically representative sample of the carbon stocks in the treatment and/or impact boundaries.
2. FIA Plot Data or the LANDFIRE FVS Ready Database (FVSRDB): If inventory data described above is not available for the treatment and/or impact boundaries, applicants may use plot/tree data from the FIA database[22] or the LANDFIRE FVS Ready Database[23] with similar stand characteristics and composition. Forest stand typing must be overseen and approved by a Registered Professional Forester or Certified Silviculturist.
3. Field Sampled Vegetation (FSVeg): For treatment and/or impact boundaries located on federally managed land, applicants may source tree lists from USFS inventories of stands with similar characteristics and composition near the treatment boundary.

Regardless of the data source, tree data should be reflective of current conditions and tree data may need to be adjusted to account for the impacts of any catastrophic events (e.g., wildfire, pest, disease, etc.) that have occurred since the inventory data was collected.

Forest Vegetation Simulator (FVS)

After collecting the necessary tree and stand data, applicants will either enter the information directly into FVS using the user interface, Suppose, or by linking FVS to a database with the information. See the FVS user manual[iv] for more information about formatting data files for use with FVS. The following step-by-step description is provided as a general guide for FVS simulations in the Suppose graphical user interface of FVS. More advanced users may use alternate approaches to carry out the same steps, such as scripting in keyword files and addfiles.

[22] FIA data can be accessed at: https://www.fia.fs.fed.us/tools-data/
[23] The LANDFIRE FVS Ready Database can be accessed at: https://www.landfire.gov/lf_fvsdb.php

To start:

i. Point Suppose to the correct working directory and the location file (.loc) to the correct database (i.e., link Suppose to the treelist);
ii. Select the “Data Preparation” menu and select “Modify/Create Locations”;
iii. Click “OK” in the pop-up window that appears and select “Edit records that define Locations using Database (Type C),”
iv. Provide a location name and enter or browse and select the data source.
v. Before running the simulation, applicants must also create an Access or Excel output file in the same location as the input file.

Next, applicants will estimate the on-site carbon stocks at the end of the project[24] in the baseline and project scenarios. Applicants will need to run the simulations twice to model the baseline and project scenarios separately following the appropriate instructions in viii and ix.

In the main FVS Suppose window:

i. Click “Select Stands” to select stands subject to treatment being modeled.
ii. Click “Set Time Scale” and enter the proposed project start date as the start year, enter the year the project will end as the end year, and enter 10 years as the cycle length.
iii. Click “Select Outputs” and select “Database Extension” and “Specify Output Database.” Select the output file where simulation data will be directed. The output database will need to exist prior to running simulations.
iv. Click “Select Outputs” and select “FFE Carbon Reports” and “Select Carbon Reports.” In the pop-up window that appears, check the three boxes “Build the Stand Carbon Report,” “Build the Harvested Carbon Report,” and “Send the Selected Carbon Reports to a Database.” Under “Biomass Predictions” select “Use Jenkins and Others (2003)” and under “Units” select “Combined (metric tons carbon/acre).”
v. For projects with pest management activities: Click “Select Outputs” and select “Event Monitor (EM) Compute Variables” and “Build Compute Table in Database.” In the pop-up window that appears, choose “0 = Yes” to add new variables to existing table and click “OK”. Next, click “Add Keywords” and select “Base FVS system,” then “All keywords,” then “Compute” and click “Accept.” In the pop-up window that appears, choose “Schedule by Year/Cycle,” enter zero in the year box, then click “Use Editor” and proceed through the editor warning. In the next pop-up window, click in the code editing box to place the cursor between the “Compute” and “End” lines, then add the following text:

    LiveCRem = TreeBio(0,0,1,All,0.,200.,0.,500.) * 0.5 * 0.907185

    This will calculate carbon (metric tons per acre) for stem and crown portions of live trees of all species removed in management activities, and record it in the

[24] For the purposes of quantification, the end of the project is defined as 50 to 80 years after project start; see Step 2 to determine the appropriate project length.

FVS_Compute output table as the variable "LiveCRem" for each projection cycle.[25] Click "Ok" and close the "Use FVS Keywords" window.

vi. It is recommended that applicants click "Outputs" and select "Base FVS Treelists" and "Build SVS Treelist" to obtain a visualization of the simulation.

vii. It is recommended that applicants click "Post Processors" and select "Error Log" to inform the applicant of errors that may occur when running the simulation.

viii. **Baseline Scenario:** In the main window, select each stand or group to which management actions will be applied by right clicking the stand, group, or "Group All". Click "Select Management" and select the category and specific actions of business-as-usual forest management activities that would be expected to occur if there were no project treatments or future threat of conversion or disturbance (e.g., harvests, natural regeneration, etc.). Customize the action to the expected practices in the absence of the project in the pop-up window that appears.[26]

Project Scenario: In the main window, select each stand or group to which management actions will be applied by right clicking the stand, group, or "Group All". Click "Select Management" and select the category and specific treatments to be implemented as part of the project, then customize the action to the particular treatment proposed in the pop-up window. If applicable, repeat the process to add forest management activities that are expected to occur after project funded treatments or conservation measures are implemented, assuming no threat of conversion or disturbance.[26]

ix. Click "Run Simulation" to name and save the file and then click "Run" in the pop-up window that appears after saving;

x. Obtain the following information from the output database to enter into the Forest Health GHG Calculator Tool, based on activity type:

Reforestation Activities (Baseline): For each stand in the treatment boundary, sum the values in the FVS_Carbon Output table for "Aboveground_Total_Live," "Belowground_Live," "Standing_Dead," and "Belowground_Dead" columns in the row for the year that the project will end. For each stand, multiply the MT C/acre at the end of the project without reforestation by the acres within the stand.[27] Sum the MT C values for all the stands to get a total for the treatment boundary (MT C).

Reforestation Activities (Project): For each stand in the treatment boundary, sum the values in the FVS_Carbon Output table for "Aboveground_Total_Live" "Belowground_Live," "Standing_Dead" and "Belowground_Dead" columns in the row for the year that the project will end. For each stand, multiply the MT C/acre at the end of the project with reforestation value by the acres within the stand.[27] Sum the MT C values for all the stands to get a total for the treatment boundary (MT C).

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[25] Further guidance on use of the Event Monitor in FVS or the TreeBio function can be found the Essential FVS guide (Dixon 2015), the Fire and Fuels Extension guide (Rebain 2010) and the Event Monitor guide (Crookston 1990; https://www.treesearch.fs.fed.us/pubs/9271)

[26] Applicants must only apply the management actions to the appropriate group (i.e., stands within the treatment or impact boundaries)

[27] These calculations can also be done within the conversions tab of the Forest Health GHG Calculator Tool.

Pest Management Activities (Baseline): For each stand in the treatment boundary, sum the values in the FVS_Carbon output table for "Aboveground_Total_Live" and "Belowground_Live" columns in the row for the year that the project will end. For each stand, multiply the MT C/acre at the end of the project without treatment or disturbance value by the acres within the stand.[27] Sum the MT C values for all the stands to get a total for the treatment boundary (MT C). Repeat this process for stands in the impact boundary.
Pest Management Activities (Project): For each stand in the treatment boundary, locate the value in the "LiveCRem" column of the "FVS_Compute" output table for the first 10 year projection cycle.[28] For each stand, multiply this value in MT C/acre by the acres within the stand, and sum the MT C removed from all stands in the treatment boundary.

Fuels Reduction Activities (Baseline): For each stand in the treatment boundary, sum the values in the FVS_Carbon output table for "Aboveground_Total_Live" and "Belowground_Live" columns in the row for the year that the project will end. For each stand, multiply the MT C/acre at the end of the project without treatment or disturbance value by the acres within the stand.[27] Sum the MT C values for all the stands to get the total for the treatment boundary (MT C). Applicants who choose to account for carbon stock change in the impact boundary[29] will repeat this process for stands in the impact boundary. Proceed to Step 3.C for guidance on determining impacts of wildfire disturbance.
Fuels Reduction Activities (Project): For each stand in the treatment boundary, sum the values in the FVS_Carbon output table for "Aboveground_Total_Live" and "Belowground_Live" columns in the row for the year that the project will end. For each stand, multiply the MT C/acre at the end of the project with treatment and without disturbance value by the acres within the stand.[27] Sum the MT C values for all the stands in the treatment boundary (MT C). Proceed to Step 3.C for guidance on determining impacts of wildfire disturbance.

Forest Conservation Activities (Baseline): For each stand in the treatment boundary, sum the values in the "Aboveground_Total_Live" "Belowground_Live," "Standing_Dead," and "Belowground_Dead" columns in the row for the year that the project will end. For each stand, multiply the MT C/acre at the end of the project without conservation value by the acres within the stand.[27] Sum the MT C values for all the stands in the treatment boundary (MT C). Sum the standing dead tree carbon values for all the stands to get a total for the treatment boundary (MT C).
Forest Conservation Activities (Project): For each stand in the treatment boundary, locate the values in the FVS_Carbon output table for "Total Removed Carbon" column for each 10 year increment of the project. For each stand,

[28] This assumes that all removals in the first cycle are part of the proposed pest management activity. If other removals not part of the pest management treatment are simulated, they should also be simulated in the Baseline scenario and applicants will subtract the value for "LiveCRem" in the Baseline from "LiveCRem" in the Project scenario to isolate removals related only to the pest management activity.
[29] Including GHG benefits from the impact boundary is optional for fuels reduction activities.

multiply the MT C/acre value by the acres within the stand and sum the MT C removed from the treatment boundary during the length of the project (MT C).[27] Applicants will use this value to inform the Forest Health GHG Calculator Tool input for the amount of biomass that will be removed and utilized during the project once the conservation easement is in place.

C. Forest Fire Models

This section provides guidance on using forest fire models to estimate the impacts of fuels reduction treatments on on-site carbon stocks within the treatment and impact boundaries (including GHG benefits from the effect of fuels treatments on fire behavior in the impact boundary is optional for fuels reduction activities). Simulating a fire in the treatment boundary can be done using the Fire and Fuels Extension of FVS[30] (FFE-FVS) or one of the alternative spatially explicit forest fire models identified in Step 1. However, because FFE-FVS simulates fire within each stand without regard to fire spread between stands, it cannot account for the effects of treatment on fire behavior outside the boundaries of the treated stands. Applicants choosing to include the GHG benefits from the impact boundary must therefore use one of the alternative spatially explicit models. In addition to general instructions, this quantification methodology provides guidance specific to modeling forest fire using FFE-FVS and FlamMap.[31] Applicants using one of the alternative models (Consume or FOFEM) must still follow the methods presented below (e.g., timing of fire simulation, sources of information for fuel and weather conditions and terrain characteristics) but the step-by-step instructions for using these models may not apply.

Using FFE-FVS to Estimate Fire Impacts in the Treatment Boundary

Table 8 describes the necessary data inputs required to estimate fire impacts on on-site carbon stocks in the baseline and project scenarios using FFE-FVS. These inputs are in addition to those required for the growth and yield models in the Step 3.B. With the exception of the fuel load, the forest fire model inputs must be consistent between the baseline and project scenarios.

Table 8. Additional Required Data Inputs for Estimating Fire Impacts on On-Site Carbon Stocks in the Treatment Boundary Using FFE-FVS

Forest Fire Model – FFE-FVS
• Year of simulated wildfire (at the midpoint of the effective period for the proposed fuels reduction treatment) • Season (e.g. before/after greenup) of simulated wildfire • Live and dead fuel moisture and weather conditions for a severe fire (e.g. 95th percentile or greater) within the project area[32] • Surface fuel models for baseline and project scenarios (applicants may override FVS fuel model selection in the input database or in management actions to reflect stand conditions and fuel succession, based on input from a Registered Professional Forester or Certified Silviculturist)

[30] In addition to the guidance provided in this quantification methodology, additional resources including user guides and training materials are available at http://www.fs.fed.us/fmsc/fvs/index.shtml

[31] In addition to the guidance provided in this quantification methodology, additional resources including user guides and training materials are available at https://www.firelab.org/project/flammap

[32] Severe fire conditions (e.g. fuel moisture, temperature, and wind speed) for the project area may be determined using remote automated weather station (RAWS) data available from the National Interagency Fire Center at http://raws.fam.nwcg.gov/index.html. Historical analysis of weather station data may be performed in FireFamilyPlus (Bradshaw and McCormick 2000).

After collecting the necessary data, applicants will estimate the on-site carbon stocks with a fire disturbance in the treatment boundary at the end of the project.[33] Applicants will need to run the simulations twice to model the baseline and project scenarios separately following the appropriate instructions in Step vi below.

i. Initialize FVS as described in Step 3.B above.
ii. Simulate a wildfire occurring at the midpoint of the effective period for the proposed fuels reduction treatment using the SIMFIRE keyword (in Suppose this can be found by keyword or by choosing Select Management > Fuel Treatments > Prescribed burn).
iii. Set keyword parameters to reflect the severe fire conditions expected for your project area.
iv. **Baseline:** Run an FVS simulation without fuels reduction treatment activity as detailed in Step vii in the previous section.
    Project: Run an FVS simulation with fuels reduction treatment activity as detailed in Step vii in the previous section.
v. Output the FVS Carbon Report as described in the previous section.
vi. Obtain the following information from the output file to enter into the Forest Health GHG Calculator Tool:
    Baseline: For each stand in the treatment boundary, sum the values in the FVS_Carbon Output table for “Aboveground_Total_Live” and “Belowground_Live” columns in the row for the year that the project will end. For each stand, multiply the MT C/acre at the end of the project without treatment but with fire disturbance value by the acres within the stand.[34] Sum the MT C values for all the stands to get a total for the treatment boundary (MT C).
    Project: For each stand in the treatment boundary, sum the values in the FVS_Carbon Output table for “Aboveground_Total_Live” and “Belowground_Live” columns in the row for the year that the project will end. For each stand, multiply the MT C/acre at the end of the project with treatment and with fire disturbance value by the acres within the stand.[34] Sum the MT C values for all the stands to get a total for the treatment boundary (MT C).

Using FlamMap to Estimate Fire Impacts in the Impact Boundary (Optional)

Effective fuels reduction treatments should reduce the proportion of the project area expected to experience high flame lengths likely to result in severe fire, therefore extending the impacts of a fuels reduction treatment beyond the treatment boundary (i.e. on the leeward side of fuels reduction treatments). Applicants that choose to include the GHG benefits from the impact boundary will need to use spatially explicit raster-type data and simulate multiple fires across the landscape using a series of randomly located ignition points in a Monte Carlo simulation to predict the probability of flame lengths greater than a specified magnitude. The output of the modelling is used

[33] For the purposes of quantification, the end of the project is defined as 50 to 80 years after project start; see Step 2 to determine the appropriate project length.
[34] These calculations can also be done within the conversions tab of the Forest Health GHG Calculator Tool.

to estimate baseline and project levels of on-site carbon stocks in the impact boundary at the end of the project[33] when there is a fire disturbance at the midpoint of the effective period for the proposed fuels reduction treatment.

Table 9 describes the necessary data inputs for performing this analysis using FlamMap. With the exception of the fuel data, the forest fire model inputs must be consistent between the baseline and project scenarios.

Table 9. Required Data Inputs for Estimating Fire Impacts on On-Site Carbon Stocks in the Impact Boundary Using FlamMap

Forest Fire Model – FlamMap
• Terrain characteristics (i.e., elevation, slope, and aspect)[35] • Fuels data (i.e., surface fuel model, canopy cover, canopy height, canopy base height, and canopy bulk density) at the midpoint of the effective period for the proposed fuels reduction treatment.[36] • Live and dead fuel moisture and weather conditions for a severe fire (e.g. 95th percentile or greater) within the project area[37]

After collecting the necessary data, applicants will estimate the on-site carbon stocks with a fire disturbance in the impact boundary at the end of the project.[33] Applicants will need to perform Steps iii and iv below twice in order to model the baseline and project scenarios separately. Step v is only carried out when modeling the baseline scenario.

i. **Impact Boundary Delineation:** Delineate the area which fuels reduction activities are intended to protect – this is the impact boundary. Applicants can determine the impact boundary based on modeled or observed fire behavior. The impact boundary could range from small area on the leeward side of a treatment to an entire fireshed. If a project involves multiple fuels reduction treatment boundaries that collectively contribute to the protection of an overlapping impact boundary, the impact boundary should be delineated as a single contiguous area. Identify which stands in your project area are within your impact boundary. Include additional stands around your impact boundary as a buffer for fire simulations.
ii. **Generate Fuel Data Layers and .LCP Files:** Applicants will need to use the data above to generate raster representations of fuels characteristics for each stand within the impact boundary. This may be performed manually or in the ArcFuels framework if using FVS (http://www.fs.fed.us/wwetac/tools/arcfuels/index.php). Topographic and fuels rasters must be combined into the FlamMap .LCP file format for use in the model. This can be accomplished using the LANDFIRE Data Access Tool (LFDAT) for ArcGIS, available from the USFS and U.S. Department of

[35] Terrain characteristics can be obtained from the USFS and U.S. Department of the Interior LANDFIRE Program http://www.landfire.gov/.
[36] Fuels data must be reflective of the stand-level data used to model forest growth in FVS for both the baseline and project scenarios. Raster layers of fuel data for 10 years.
[37] Severe fire conditions (e.g. fuel moisture, temperature, and wind speed) for the project area may be determined using weather station data (e.g. RAWS) and expert opinion. Historical analysis of weather station data may be performed in FireFamilyPlus (Bradshaw and McCormick 2000).

the Interior LANDFIRE Program http://www.landfire.gov/. Applicants will need two .LCP files, one for the baseline scenario and one for the project scenario.

iii. **Simulate Ignitions:** Load the.LCP files into FlamMap, and perform Monte Carlo simulations using the Minimum Travel Time model embedded in FlamMap (FlamMap-MTT). Applicants must perform the simulations twice to obtain separate output for the baseline and project scenarios. Applicants must use the same weather scenario used to simulate fire within the treatment boundary (e.g., in FVS) and may generate spatially explicit wind vectors from a domain-wide wind speed and direction. MTT runs must use randomly located ignition points. To simulate fires of a size representative of expected fire spread under severe conditions, applicants must set a minimum density of one ignition per 50 acres and a minimum burn period of eight hours.

iv. **Flame Length Probability Output:** The Flame Length Probability (FLP) table output from the simulations gives the expected probability of flame lengths in 2 foot (English) or 0.5 meter (Metric) bins for each raster grid cell (pixel) in the impact boundary. Determine which pixels within the impact boundary have a >50% probability of flame lengths greater than 8 ft. or 2.5 m. Calculate the percentage of pixels within the impact boundary that meet this condition in the baseline and project scenarios. Applicants will enter these percentages for the baseline and project scenarios into the Forest Health GHG Calculator Tool which will calculate the percent reduction in severe fire area.

v. **On-Site Carbon Stock Output (Baseline Scenario Only):** After simulating fire in year 10, return to FVS or alternate growth and yield model to project the growth of the remaining standing live trees in the impact boundary to the year that the project will end.[33] For each stand in the impact boundary, obtain the standing live carbon output at the end of the project with fire disturbance and without treatment. For each stand, multiply the MT C/acre value by the acres within the stand.[38] Sum the standing live tree carbon values for all the stands in the impact boundary (MT C).

[38] These calculations can also be done within the conversions tab of the Forest Health GHG Calculator Tool.

Step 4: Determine Look-Up Values for the Forest Health GHG Calculator Tool

A. On-Site Carbon Look Up Table for Reforestation Activities

Applicants that use COLE to estimate the on-site carbon stocks in the project scenario of a reforestation activity must use the values in Table 10 to determine the on-site carbon stocks at the end of the project in the baseline scenario.[39] The values in Table 10 are based on COLE outputs from FIA plots on nonstocked and poorly stocked lands statewide. Applicants will use the on-site carbon value(s) (MT C/acre) that applies to the length of the project (50, 60, or 80 years based on site class).

Table 10. Baseline On-Site Carbon for Reforestation Activities

Forest Practice Site Class / End of Project	Carbon Pool	On-Site Carbon in Baseline (MT C/acre)
I / 50 Years	Standing Live	24.79
	Standing Dead	4.69
II / 60 Years	Standing Live	20.17
	Standing Dead	4.71
III / 60 Years	Standing Live	16.82
	Standing Dead	4.31
IV / 80 Years	Standing Live	15.13
	Standing Dead	3.59
V / 80 Years	Standing Live	12.71
	Standing Dead	3.01

For reforestation and forest conservation activities, sum the appropriate values for standing live and standing dead carbon (MT C/acre) and then multiply that value by the acres within the treatment boundary to convert to MT C.

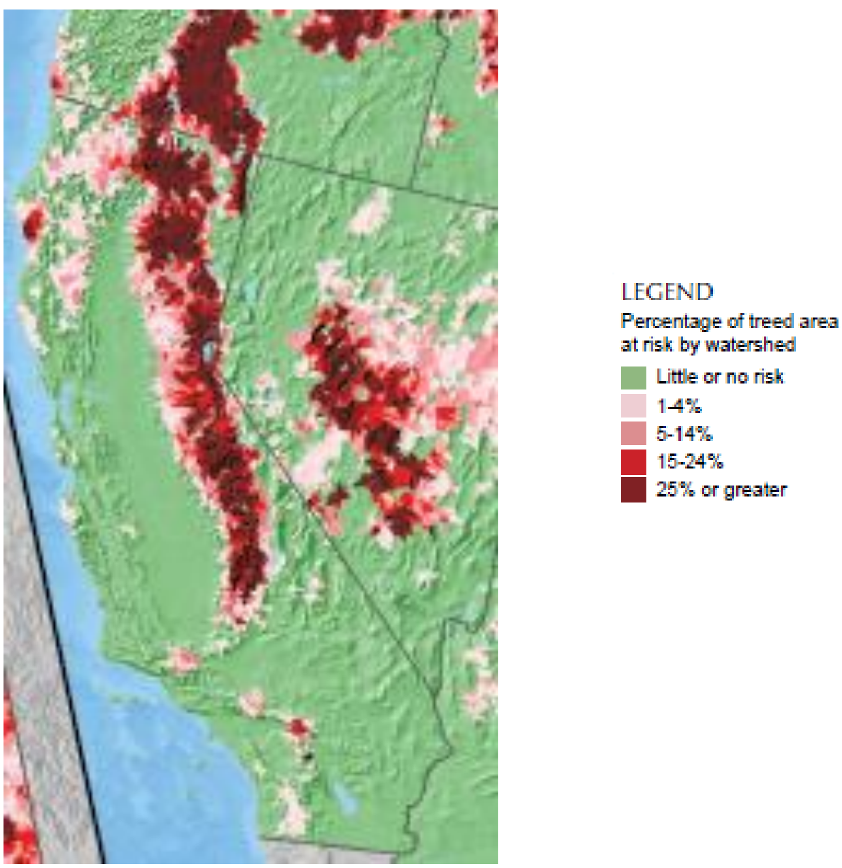
For pest management activities, only use the appropriate value for standing live tree carbon (MT C/acre) and multiply that by the total acres within the treatment and impact boundaries.

[39] Table 10 does not apply to applicants that use FVS to estimate on-site carbon stocks for a reforestation activity. These applicants must use FVS values for both the baseline and project scenarios.

B. National Insects and Disease Risk Map for Pest Management Activities

Applicants with projects that include pest management activities must determine the percentage of treed area within the treatment and impact boundaries at risk from pests and disease within a 10-year timeframe. Applicants may provide: 1) a site-specific estimate sourced from NIDRM, 2) a site-specific estimate sourced from published, peer-reviewed literature directly applicable to the project site, or 3) a site-specific estimate from a Registered Professional Forester familiar with the threat facing the project site. If using NIDRM, applicants must identify the level of risk associated with the treatment and impact boundaries of the pest management activity from the NIDRM map displayed in Figure 2 and available at: http://www.fs.fed.us/foresthealth/technology/pdfs/NIDRM_2012_2x3_Subwatersheds.pdf. If the project is in an area where the risk category is presented as a range (i.e., 1-4%, 5-14%, or 15-24%), use the middle of the range as the risk level for determining on-site carbon stocks. If the project is in an area where the risk is in the 25% or greater category, use 25% as the risk level.

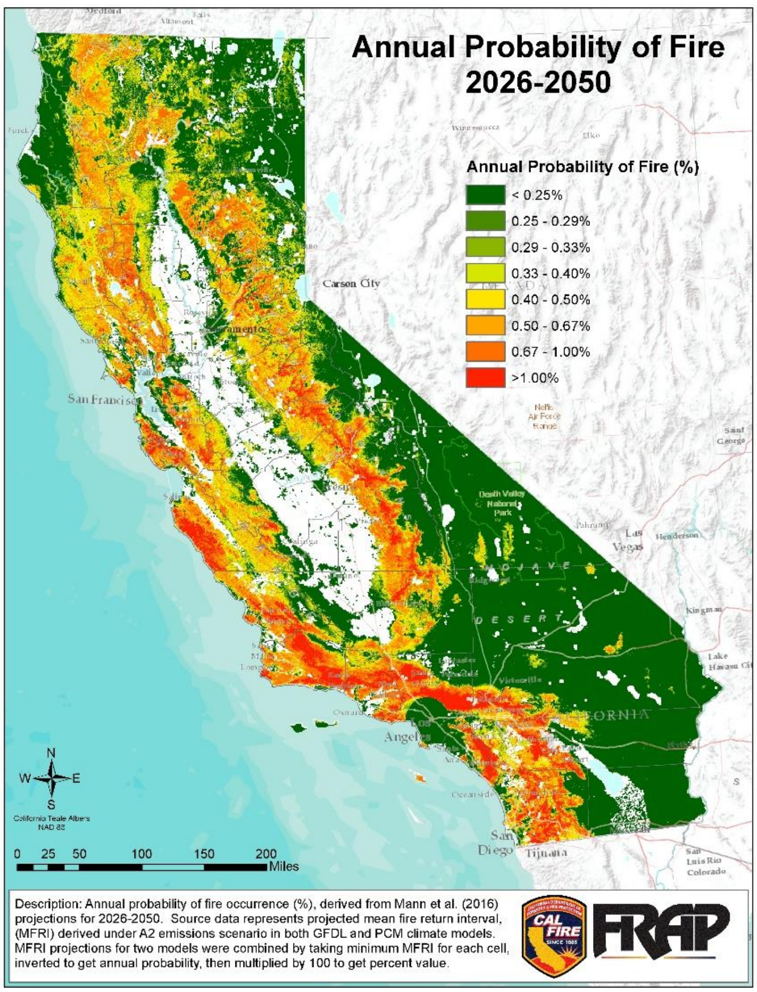
Figure 2. 2013-2027 National Insect and Disease Composite Risk Map by Subwatersheds



C. Fire Probability Map for Fuels Management Activities

Applicants with projects that include fuels reduction activities must determine the likelihood of the area within the fuels reduction treatment and impact boundaries being subject to wildfire disturbance within the effective period of the fuels treatment. Applicants must identify the mean annual probability of fire occurrence specific to the area within the treatment and impact boundaries[40] using the CAL FIRE Fire and Resource Assessment Program's (FRAP) Fire Probability for Carbon Accounting interactive map tool available at: http://frap.fire.ca.gov/projects/fireProbability and displayed in Figure 3.[41] While the map presented below expresses probability as ranges, applicants will use the interactive online tool to determine a discrete value for the mean probability of fire in the area containing treatment and impact boundaries to be used for the purposes of GHG quantification. The fire occurrence probability must be the same in the baseline and project scenarios.

Figure 3. Fire Probability for Carbon Accounting Map



[40] If the tool does not contain data for the area within the treatment and impact boundaries, applicants can use the fire probability of the HUC12 Watershed that these areas fall within.

[41] CAL FIRE released a draft Fire Probability for Carbon Accounting Map in February 2017.

Step 5: Estimate Net GHG Benefit for the Proposed Project Using the Forest Health GHG Calculator Tool

Applicants must use the Forest Health GHG Calculator Tool to complete this step. The Calculator Tool can be downloaded from www.arb.ca.gov/cci-quantification.

Users should begin with the **Read Me** tab, which contains instructions and prompts users to enter project information. Key terms are defined in the **Definitions** tab. The **calculation** tabs identify inputs required by the user, generally requiring project-specific data or assumptions. Landscape level projects may include multiple activities of the same or differing types. The GHG Calculator Tool contains activity-specific workbooks and allows for multiple entries within each workbook.
Input and output fields are color coded:

- Yellow fields indicate a direct user input is required.
- Green fields indicate a selection from a drop-down box is required.
- Gray fields indicate output or calculation fields that are automatically populated based on user entries and the calculation methods.

Details of calculation methods are provided in Appendix A.

The **GHG Summary** tab displays the total project GHG benefit as well as the estimated total project GHG benefit per Forest Health Program GGRF dollar and per total GGRF dollar requested, as described below.

- **Total Project GHG Benefit** is equal to the sum total of each of the GHG benefits calculated in Section B and are automatically summed in the Forest Health GHG Calculator Tool in the **GHG Summary** tab.

- **Total Project GHG Benefit per Dollar of Forest Health Program GGRF Funds Requested** is calculated as:

$$\frac{Total\ Project\ GHG\ Benefit\ in\ Metric\ Tons\ of\ CO_2e}{Forest\ Health\ GGRF\ Funds\ Requested\ (\$)}$$

  Applicants should enter the Forest Health GGRF Funds Requested ($) for all project features into the Forest Health GHG Calculator Tool. This amount is equal to the amount of GGRF dollars the applicant is requesting from CAL FIRE's Forest Health Program. The Forest Health GHG Calculator Tool will provide the Total Project GHG Benefit per Forest Health GGRF Funds Requested.

- **Total Project GHG Benefit per Dollar of GGRF Requested** is calculated as:

$$\frac{Total\ Project\ GHG\ Benefit\ in\ Metric\ Tons\ of\ CO_2e}{Total\ GGRF\ Funds\ Requested\ (\$)}$$

Applicants should enter the Total GGRF Funds Requested ($) into the Forest Health GHG Calculator Tool for all project features. This amount is equal to the amount of GGRF dollars the applicant is requesting from CAL FIRE's Forest Health Program, plus all GGRF dollars from CAL FIRE or other agencies that have previously been awarded to the same project and any GGRF dollars from agencies other than CAL FIRE that the project has or plans to apply for. For a list of GGRF funded programs, go to: www.arb.ca.gov/cci-events. If no other GGRF funds are requested, this will be the same amount as the Forest Health Program GGRF Funds Requested. The Forest Health GHG Calculator Tool will provide the Total Project GHG Benefit per GGRF Funds Requested.

Section C. Documentation

In addition to Forest Health Program application requirements, applicants for GGRF funding are required to document results from the use of this quantification methodology, including supporting materials to verify the accuracy of project-specific inputs.

Applicants are required to provide electronic documentation that is complete and sufficient to allow the calculations to be reviewed and replicated. Paper copies of supporting materials must be available upon request by agency staff.

The following checklist is provided as a guide to applicants; additional data and/or information may be necessary to support project-specific input assumptions.

	Documentation Description	Completed
1.	Project description, including excerpts or specific references to the location in the main Forest Health Program application of the project information necessary to complete the applicable portions of the quantification methodology	
2.	Populated Forest Health GHG Calculator Tool file (in .xls) with worksheets applicable to the project populated (ensure that the Total Project GHG Benefit, Total Project GHG Benefit/Forest Health GGRF Funds Requested, and Total Project GHG Benefit/Total GGRF Funds Requested fields in the summary worksheet contain calculated values)	
3.	If the Total GGRF Funds Requested are different than the Forest Health GGRF Funds Requested, identify the other GGRF program(s) where funding is sought, including the fiscal year of the application(s)	
4.	Electronic copies of spreadsheets supporting the inputs for the Forest Health GHG Calculator Tool	
5.	Any other information as necessary and appropriate to substantiate inputs (e.g., DBH, tree planting site characteristics, etc.)	

Section D. Reporting after Funding Award

Accountability and transparency are essential elements for all GGRF California Climate Investment projects. As described in CARB's Funding Guidelines for Agencies that Administer California Climate Investments (Funding Guidelines),[42] each administering agency is required to track and report on the benefits of the California Climate Investments funded under their program(s). Each project funded by the GGRF is expected to provide a real and quantifiable net GHG benefit. The previous sections of this document provide the methods and tools to estimate the net GHG benefit of a proposed project based on project characteristics and assumptions of expected conditions and activity levels. This section explains the minimum reporting requirements for administering agencies and funding recipients during project implementation, termed Phase 1, and after a project is completed, termed Phase 2. Table 11 below shows the project phases and when reporting is required.

Table 11. Quantification and Reporting By Project Phase

	Timeframe & Reporting Frequency	Quantification Methods
Project Selection	Period from solicitation to selection of projects and funding awards. Applicant submits application to CAL FIRE by due date in solicitation materials.	All applicants use methods in CARB's quantification methodology to estimate the net GHG benefit of the project.
Phase 1	Period from project award date through project completion date. CAL FIRE reports to CARB on an annual basis.	All awarded projects use methods in CARB's quantification methodology to update initial estimate of net GHG benefit, as needed, based on project changes.
Phase 2	Begins after project completion. CAL FIRE reports to CARB consistent with the Funding Guidelines.	GHG reduction estimates are updated and reported for a subset of awarded projects.

Funding recipients have the obligation to provide, or provide access to, data and information on project outcomes to CAL FIRE. Applicants should familiarize themselves with the requirements below as well as those within the Forest Health Program solicitation materials (e.g., guidelines, applications, etc.), and grant agreement.

It is the responsibility of administering agencies to collect and compile project data from funding recipients, including the net GHG benefit and information on benefits to disadvantaged communities.

Phase 1 reporting is required for all forest health projects. CAL FIRE will collect and submit data to CARB to satisfy Phase 1 reporting requirements. Projects must report

[42] California Air Resources Board. Funding Guidelines for Agencies Administering California Climate Investments. (December 21, 2015). www.arb.ca.gov/cci-fundingguidelines

any changes that impact net GHG benefit (i.e., assumptions or quantities) to CARB prior to project completion.

Phase 2 reporting is required for only a subset of forest health projects and is intended to document actual project benefits achieved after the project becomes operational. Phase 2 data collection and reporting will not be required for every project. CAL FIRE will be responsible for identifying the subset of individual projects that must complete Phase 2 reporting, identifying who will be responsible for collecting Phase 2 data, and for reporting the required information to CARB. CARB will work with CAL FIRE to address Phase 2 procedures, including but not limited to:

- The **timelines** for Phase 2 reporting, i.e., when does Phase 2 reporting begin, how long will Phase 2 reporting be needed.
- As applicable, **approaches for determining the subset of projects** that need Phase 2 reporting (i.e., how many **X** projects out of **Y** total projects are required to have Phase 2 reporting).
- **Methods for monitoring or measuring** the necessary data to quantify and document achieved GHG reductions and other select project benefits.
- **Data to be collected**, including data fields needed to support quantification of GHG emission benefits.
- Reporting requirements for transmitting the data to CARB or CAL FIRE for program transparency and use in reports.

Once the Phase 2 quantification method and data needs are determined, CARB will develop and post the final CARB approved Phase 2 methodology for use in Phase 2 reporting.

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[i] As described in Volume 1 of the California Air Resources Board. Funding Guidelines for Agencies Administering California Climate Investments (December 21, 2015) (Funding Guidelines). www.arb.ca.gov/cci-fundingguidelines

[ii] California Air Resources Board Greenhouse Gas Interim Quantification Methodology for the California Department of Forestry & Fire Protection Forest Management Program, Fiscal Year 2014-15. Available at: www.arb.ca.gov/cci-quantification.

[iii] California Air Resources Board. Funding Guidelines for Agencies Administering California Climate Investments (December 21, 2015). www.arb.ca.gov/cci-fundingguidelines

[iv] United States Forest Service. Essential FVS: A user's guide to the Forest Vegetation Simulator (2015). Available at: http://www.fs.fed.us/fmsc/ftp/fvs/docs/gtr/EssentialFVS.pdf

Section E. References

The following references were used in the development of this quantification methodology and the accompanying Forest Health GHG Calculator Tool.

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Appendix A. Equations Supporting the Forest Health GHG Calculator Tool

Methods used in the Forest Health GHG Calculator Tool for estimating the net GHG benefit by activity type are provided in this appendix. The net GHG benefit from the project is quantified within the Forest Health GHG Calculator Tool using the equations below. For more detail about the equation and GHG Calculator Tool inputs, see Table 4 of this quantification methodology. Additional information about the emission factors used is available in the GHG Calculator Tool.

A. GHG Benefit from Reforestation Activities

The GHG benefit from reforestation activities is calculated as the difference between the baseline and project scenarios using Equation 1. Equation 2 is used to determine the carbon storage and project emissions in the project scenario. Equation 3 is used to determine the carbon storage in the baseline scenario.

Equation 1: GHG Benefit from Reforestation Activities

$$GHG_R = GHG_{RP} - GHG_{RB}$$

Where,			Units
GHG_R	=	GHG benefit of reforestation activities	MT CO_2e
GHG_{RP}	=	On-site carbon storage and project emissions in reforestation project scenario (from Equation 2)	MT CO_2e
GHG_{RB}	=	On-site carbon storage in reforestation baseline scenario (from Equation 3)	MT CO_2e

Equation 2: On-Site Carbon Storage and Project Emissions in Reforestation Project Scenario

$$GHG_{RP} = CT_{RP} \times 3.67 - MC_{RP} \times ASP_{RP} - AHT_{RP} \times 0.0607$$

Where,			Units
GHG_{RP}	=	On-site carbon storage and project emissions in reforestation project scenario	MT CO_2e
CT_{RP}	=	Carbon within the treatment boundary at the end of the project with reforestation (from FVS or COLE)	MT C
3.67	=	Conversion factor from C to CO_2e	CO_2e/C
MC_{RP}	=	Mobile combustion emission factor if site preparation takes place in reforestation project scenario (based on level of brush cover)	MT CO_2e/ Acre
ASP_{RP}	=	Area subject to site preparation	Acres
AHT_{RP}	=	Area subject to herbicide treatment	Acres
0.0607	=	Herbicide treatment emission factor	MT CO_2e/ Acre

Equation 3: On-Site Carbon Storage in Reforestation Baseline Scenario

$$GHG_{RB} = CT_{RB} \times 3.67 + SHU_{RB} \times ASP_{RP}$$

Where,			Units
GHG_{RB}	=	On-site carbon storage in reforestation baseline scenario	MT CO_2e
CT_{RB}	=	Carbon within the treatment boundary at the end of the project without reforestation (from FVS or Table 10)	MT C
3.67	=	Conversion factor from C to CO_2e	CO_2e/C
SHU_{RB}	=	Shrubs and herbaceous understory carbon removed during site preparation from within the treatment boundary in reforestation project scenario (based on land cover type)	MTCO_2e/ Acre
ASP_{RP}	=	Area subject to site preparation	Acres

B. GHG Benefit from Pest Management Activities

The GHG benefit from pest management activities is calculated as the difference between the baseline and project scenarios using Equation 4. Equation 5 is used to determine the carbon storage and project emissions in the project scenario. Equation 6 is used to determine the carbon storage in the baseline scenario.

Equation 4: GHG Benefit from Pest Management Activities

$$GHG_{PM} = GHG_{PMP} - GHG_{PMB}$$

Where,

			Units
GHG_{PM}	=	GHG benefit of pest management activities	MT CO_2e
GHG_{PMP}	=	On-site carbon storage and project emissions in pest management project scenario (from Equation 5)	MT CO_2e
GHG_{PMB}	=	On-site carbon storage in pest management baseline scenario (from Equation 6)	MT CO_2e

Equation 5: On-Site Carbon Storage and Project Emissions in Pest Management Project Scenario

$$GHG_{PMP} = [(CT_{PMNT} + CI_{PMNT}) \times (1 - R_{PMP}) - CR_{PMP}] \times 3.67 - BR_{PMP} \times 0.06$$

Where,

			Units
GHG_{PMP}	=	On-site carbon storage and project emissions in pest management project scenario	MT CO_2e
CT_{PMNT}	=	Carbon within the treatment boundary at the end of the project without disturbance or pest management treatment (from FVS or COLE)	MT C
CI_{PMNT}	=	Carbon within the impact boundary at the end of the project without disturbance or pest management treatment (from FVS or COLE)	MT C
R_{PMP}	=	Percentage of treatment and impact boundaries at risk with pest management treatment	%
CR_{PMP}	=	Carbon removed as part of pest management treatment	MT C
3.67	=	Conversion factor from C to CO_2e	CO_2e/C
BR_{PMP}	=	Biomass removed via mechanical treatments	Bone dry tons
0.06	=	Mobile combustion emission factor for biomass removal in pest management project scenario	MT CO_2e/ bone dry ton

Equation 6: On-Site Carbon Storage in Pest Management Baseline Scenario

$$GHG_{PMB} = (SLT_{PMNT} + SLI_{PMNT}) \times (1 - R_{PMB}) \times 1.24 \times 3.67$$

Where,			Units
GHG_{PMB}	=	On-site carbon storage in pest management baseline scenario	MT CO_2e
SLT_{PMNT}	=	Standing live tree carbon within the treatment boundary at the end of the project without disturbance or pest management treatment (from FVS or COLE)	MT C
SLI_{PMNT}	=	Standing live tree carbon within the impact boundary at the end of the project without disturbance or pest management treatment (from FVS or COLE)	MT C
R_{PMB}	=	Percentage of treatment and impact boundaries at risk without pest management treatment.	%
1.24	=	Multiplier to account for below-ground carbon (0.24 root-to-shoot ratio)	Total C/ above-ground C
3.67	=	Conversion factor from C to CO_2e	CO_2e/C

C. GHG Benefit from Fuels Reduction Activities

The GHG benefit from fuels reduction activities is calculated as the difference between the baseline and project scenarios using Equation 7. Equation 8 is used to determine the carbon storage and project emissions in the project scenario. Equation 9 is used to determine the carbon storage in the baseline scenario.

Equation 7: GHG Benefit from Fuels Reduction Activities

$$GHG_{FR} = GHG_{FRP} - GHG_{FRB}$$

Where,			Units
GHG_{FR}	=	GHG benefit of fuels reduction activities	MT CO_2e
GHG_{FRP}	=	On-site carbon storage and project emissions in fuels reduction project scenario (from Equation 8)	MT CO_2e
GHG_{FRB}	=	On-site carbon storage in fuels reduction baseline scenario (from Equation 9)	MT CO_2e

Equation 8: On-Site Carbon Storage and Project Emissions in Fuels Reduction Project Scenario

$$GHG_{FRP} = [CTNF_{FRP} + CINF_{FR} - (1 - (1 - APFO_{FR})^{EP}) \times (CTNF_{FRP} + CINF_{FR} - CTWF_{FRP} - (CINF_{FR} - (CINF_{FR} - CIWF_{FRB}) \times (1 - (IFL_B - IFL_P))))] \times 3.67 - BR_{FRP} \times 0.06$$

Where,			Units
GHG_{FRP}	=	On-site carbon storage and project emissions in fuels reduction project scenario	MT CO_2e
$CTNF_{FRP}$	=	Carbon within the treatment boundary at the end of the project with fuels reduction treatment but without fire disturbance (from FVS)	MT C
$CINF_{FR}$	=	Carbon within the impact boundary at the end of the project without fire disturbance (from FVS) (optional)	MT C
$APFO_{FR}$	=	Annual probability of fire occurrence within the treatment and impact boundaries (mean probability from FRAP Fire Probability for Carbon Accounting map tool)	%
EP	=	Effective period for fuels reduction treatment (maximum 25 years)	Years
$CTWF_{FRP}$	=	Carbon within the treatment boundary at the end of the project with fuels reduction treatment and with fire disturbance (from FVS and FlamMap)	MT C
$CIWF_{FRB}$	=	Carbon within the impact boundary at the end of the project without fuels reduction treatment but with fire disturbance(from FVS and FlamMap) (optional)	MT C
IFL_B	=	Proportion of impact boundary likely to burn at high severity with fuels reduction treatment (optional)	%
IFL_P	=	Proportion of impact boundary likely to burn at high severity with fuels reduction treatment (optional)	%
3.67	=	Conversion factor from C to CO_2e	CO_2e/C
BR_{FRP}	=	Biomass removed via mechanical treatments	Bone dry tons
0.06	=	Mobile combustion emission factor for biomass removal in fuels reduction project scenario	MT CO_2e/ bone dry ton

Equation 9: On-Site Carbon Storage in Fuels Reduction Baseline Scenario

$$GHG_{FRB} = [CTNF_{FRB} + CINF_{FR} - (1 - (1 - APFO_{FR})^{EP}) \times (CTNF_{FRB} + CINF_{FR} - CTWF_{FRB} - CIWF_{FRB})] \times 3.67$$

Where,			Units
GHG_{FRB}	=	On-site carbon storage in fuels reduction baseline scenario	MT CO_2e
$CTNF_{FRB}$	=	Carbon within the treatment boundary at the end of the project without fuels reduction treatment and without fire disturbance(from FVS)	MT C
$CINF_{FR}$	=	Carbon within the impact boundary at the end of the project without fire disturbance (from FVS) (optional)	MT C
$CTWF_{FRB}$	=	Carbon within the treatment boundary at the end of the project without fuels reduction treatment but with fire disturbance(from FVS and FEE-FVS)	MT C
$CIWF_{FRB}$	=	Carbon within the impact boundary at the end of the project without fuels reduction treatment but with fire disturbance (from FVS and FlamMap) (optional)	MT C
$APFO_{FR}$	=	Annual probability of fire occurrence within the treatment and impact boundaries (mean probability from FRAP Fire Probability for Carbon Accounting map tool)	%
EP	=	Effective period for fuels reduction treatment (maximum 25 years)	Years
3.67	=	Conversion factor from C to CO_2e	CO_2e/C

D. GHG Benefit from Forest Conservation Activities

The GHG benefit from forest conservation activities is calculated as the difference between the baseline and project scenarios using Equation 10. Equation 11 is used to determine the on-site carbon storage in the project scenario. Equation 12 is used to determine the on-site carbon storage in the baseline scenario. Note: If biomass will be removed and utilized in the project scenario, or would be in the baseline scenario, the net GHG benefit from utilization is calculated using Equations 13-17.

Equation 10: GHG Benefit from Forest Conservation Activities

$$GHG_{FC} = GHG_{FCP} - GHG_{FCB}$$

Where,			Units
GHG_{FC}	=	GHG benefit of forest conservation activities	MT CO_2e
GHG_{FCP}	=	On-site carbon storage in forest conservation project scenario (from Equation 11)	MT CO_2e
GHG_{FCB}	=	On-site carbon storage in forest conservation baseline scenario (from Equation 12)	MT CO_2e

Equation 11: On-Site Carbon Storage in Forest Conservation Project Scenario

$$GHG_{FCP} = C_{FCP} \times 3.67$$

Where,			Units
GHG_{FCP}	=	On-site carbon storage and project emissions in forest conservation project scenario	MT CO_2e
C_{FCP}	=	Standing live tree carbon within the treatment boundary at the end of the project with the conservation easement (FVS or COLE)	MT C
3.67	=	Conversion factor from C to CO_2e	CO_2e/C

Equation 12: On-Site Carbon Storage in Forest Conservation Baseline Scenario

$$GHG_{FCB} = C_{FCP} \times \left(100\% - CI_{FCB}\right) \times 3.67$$

Where,			Units
GHG_{FCB}	=	On-site carbon storage in forest conservation baseline scenario	MT CO_2e
C_{FCP}	=	Standing live tree carbon within the treatment boundary at the end of the project with the conservation easement (from FVS or COLE)	MT C
CI_{FCB}	=	Conversion impact within the treatment boundary (based on type of conversion threat)	%
3.67	=	Conversion factor from C to CO_2e	CO_2e/C

E. GHG Benefit from Biomass Utilization Activities

Biomass may be removed and utilized for wood products or electricity generation as part of the project.[43] The GHG benefit from biomass utilization activities is calculated as the sum of the benefits of activities that result in carbon being stored long-term in wood products, the displacement of fossil fuel-based energy with biomass energy, and avoidance of biomass disposal emissions using Equation 13.

Equation 13: GHG Benefit from Biomass Utilization Activities

$$GHG_{BU} = GHG_{WP} + GHG_{EG} + GHG_{AE}$$

Where,			Units
GHG_{BU}	=	GHG benefit of biomass utilization activities	MT CO_2e
GHG_{WP}	=	GHG benefit from utilizing biomass for wood products (from Equation 15)	MT CO_2e
GHG_{EG}	=	GHG benefit from utilizing biomass for electricity generation (from Equation 16)	MT CO_2e
GHG_{AE}	=	GHG benefit from avoided biomass disposal emissions (only applicable to biomass utilization activities for biomass *not* removed by other GGRF funded project activities; i.e., biomass that would be removed in the absence of the project) (from Equation 17)	MT CO_2e

The GHG benefit from carbon stored long-term in wood products is calculated based on the net quantity of biomass utilized for wood products, mill efficiency, and the carbon storage factor of the wood products generated. Equation 14 is used to determine the net amount of carbon transferred to wood products as a result of project activities. Projects may use the actual efficiency from the mill where trees will be delivered, supported with documentation, or the appropriate default mill efficiency provided in Table 12. If trees will be delivered to more than one mill with different efficiencies, applicants may provide a weighted mill efficiency. After determining the carbon transferred to wood products, Equation 15 is used to determine the net amount of carbon stored long term in wood products as a result of project activities. To do this, determine the percentage of removed biomass that will go into each wood product class category. If not available from the mill that wood is delivered to, assume that 100% of the biomass goes into "miscellaneous products." Default carbon storage factors, the percent of carbon transferred to wood products that remains stored long-term, are provided.

[43] Most project activities are not expected to impact long-term biomass removal and utilization over the 50-80 year project life and it is assumed to be equal in the baseline and project scenarios for all project types except forest conservation where land that would be converted continues to operate as a working forest. Biomass that would be removed and utilized in the conservation baseline scenario due to conversion and biomass that would be removed and utilized in the project scenario due to ongoing forest management are therefore included in the biomass utilization calculations.

Equation 14: Carbon Transferred to Wood Products

$$C_{WP} = \left(BWP_P - BWP_{FCB} + BWP_{FCP}\right) \times 0.5 \times ME$$

Where,			Units
C_{WP}	=	Carbon transferred to wood products	MT C
BWP_P	=	Biomass to be removed from the project area (with and without GGRF funding) and delivered to a mill to be utilized for wood products in the project scenario	Bone dry tons (BDT)
BWP_{FCB}	=	Biomass that would be removed from within the forest conservation treatment boundary and utilized for wood products without the conservation easement	BDT
BWP_{FCP}	=	Biomass that is expected to be removed from within the forest conservation treatment boundary and utilized for wood products with conservation easement	BDT
0.5	=	Conversion factor from wood to carbon	C/wood
ME	=	Mill efficiency	%

Table 12. Default Mill Efficiency

Hardwood	Softwood
56.8%	67.5%

Equation 15: GHG Benefit of Carbon Stored Long-Term in Wood Products

$$GHG_{WP} = [(C_{WP} \times SL \times 0.463) + (C_{WP} \times HL \times 0.250) + (C_{WP} \times SP \times 0.484) + (C_{WP} \times OS \times 0.582) + (C_{WP} \times NP \times 0.380) + (C_{WP} \times P \times 0.058) + (C_{WP} \times MP \times 0.176)] \times 3.67$$

Where,			Units
GHG_{WP}	=	GHG benefit of carbon stored in wood products	MT CO_2e
C_{WP}	=	Carbon transferred to wood products	MT C
SL	=	Percentage of biomass that will go into softwood lumber	%
0.463	=	Carbon storage factor for softwood lumber	%
HL	=	Percentage of biomass that will go into hardwood lumber	%
0.250	=	Carbon storage factor for hardwood lumber	%
SP	=	Percentage of biomass that will go into softwood plywood	%
0.484	=	Carbon storage factor for softwood plywood	%
OS	=	Percentage of biomass that will go into oriented standboard	%
0.582	=	Carbon storage factor for oriented standboard	%
NP	=	Percentage of biomass that will go into nonstructural panels	%
0.380	=	Carbon storage factor for nonstructural panels	%
P	=	Percentage of biomass that will go into paper	%
0.058	=	Carbon storage factor for paper	%
MP	=	Percentage of biomass that will go into miscellaneous products	%
0.176	=	Carbon storage factor for miscellaneous products	%
3.67	=	Conversion factor from C to CO_2e	CO_2e/C

The GHG benefit from utilizing biomass for electricity generation is calculated as the net quantities of biomass utilized for electricity generation via combustion and gasification, multiplied by a process specific emission reduction factor. Equation 16 is used to determine the net GHG benefit from generating electricity.

Equation 16: GHG Benefit from Utilizing Biomass for Electricity Generation

$$GHG_E = \left(BEC_P - BEC_{FCB} + BEC_{FCP}\right) \times 0.25 + \left(BEG_P - BEG_{FCB} + BEG_{FCP}\right) \times 0.32$$

Where,			Units
GHG_E	=	GHG benefit from utilizing biomass for electricity generation	MT CO_2e
BEC_P	=	Biomass to be removed from the project area (with and without GGRF funding) and delivered to a biomass facility generating electricity via combustion as part of the project	Bone dry tons (BDT)
BEC_{FCB}	=	Biomass that would be removed from within the forest conservation treatment boundary and utilized for electricity generation via combustion without the conservation easement	BDT
BEC_{FCP}	=	Biomass that is expected to be removed from within the forest conservation treatment boundary and utilized for electricity generation via combustion with the conservation easement	BDT
0.25	=	Emission reduction factor for electricity generation via combustion	MT CO_2e/ BDT
BEG_P	=	Biomass to be removed from the project area (with and without GGRF funding) and delivered to a biomass facility generating electricity via gasification as part of the project	BDT
BEG_{FCB}	=	Biomass that would be removed from within the forest conservation treatment boundary and utilized for electricity generation via gasification without the conservation easement	BDT
BEG_{FCP}	=	Biomass that is expected to be removed from within the forest conservation treatment boundary and utilized for electricity generation via gasification with the conservation easement	BDT
0.32	=	Emission reduction factor for electricity generation via gasification	MT CO_2e/ BDT

If the project funds the utilization of biomass removed as part of management practices not associated with the project (i.e., the forest treatment was not funded by the GGRF grant but complementary services such as transportation to a biomass facility or mill is funded with GGRF grant money), the project may include the GHG benefit of avoided CH_4 and N_2O emissions[44] from an open pile burn, landfilling, or leaving biomass to decay on-site using Equation 17. No credit is given for avoiding disposal emissions of material that would only require disposal as a result of the project (i.e., biomass removed as part of GGRF-funded forest treatments).

Equation 17: GHG Benefit from Avoided Biomass Disposal Emissions

$$GHG_{AE} = [(BDT_{PBB} \times 0.16) + (BDT_{LB} \times 0.21) + (BDT_{DB} \times 1.25)] \times 0.907185$$

Where,			Units
GHG_{AE}	=	Avoided emissions from open pile burning, landfilling, or leaving biomass to decay on-site	MT CO_2e
BDT_{PBB}	=	Biomass that would be removed and open pile burned without the project	Bone dry tons (BDT)
0.16	=	Emission factor for open pile burning of removed biomass	Ton CO_2e /BDT
BDT_{LB}	=	Biomass that would be removed and landfilled without the project	BDT
0.21	=	Emission factor for landfilling removed biomass	Ton CO_2e /BDT
BDT_{DB}	=	Biomass that would be removed and left to decay on-site without the project	BDT
1.25	=	Emission factor for leaving removed biomass to decay on-site	Ton CO_2e /BDT
0.907185	=	Conversion factor from ton to metric ton	MT/ton

[44] Biogenic CO2 emissions are excluded consistent with the CARB GHG inventory accounting methods.

F. Net GHG Benefit from Project Activities

The net GHG benefit from any project is the sum of the GHG benefit from reforestation, pest management, fuels reduction, forest conservation and biomass utilization activities. Equation 18 is used to determine the net GHG benefit from forest health projects.

Equation 18: Net GHG Benefit

$$GHG = \left(GHG_R + GHG_{PM} + GHG_{FR} + GHG_{FC} + GHG_{BU}\right)$$

Where,			Units
GHG	=	Net GHG benefit from the project	MT CO_2e
GHG_R	=	GHG benefit from reforestation activities	MT CO_2e
GHG_{PM}	=	GHG benefit from pest management activities	MT CO_2e
GHG_{FR}	=	GHG benefit from fuels reduction activities	MT CO_2e
GHG_{FC}	=	GHG benefit from forest conservation activities	MT CO_2e
GHG_{BU}	=	GHG benefit from biomass utilization activities	MT CO_2e